

# Modulation of AIRS Mid-tropospheric CO<sub>2</sub> by the Large-scale Circulations

Xun Jiang<sup>1</sup>, Edward Olsen<sup>2</sup>, Thomas Pagano<sup>2</sup>, and Yuk Yung<sup>3</sup>

<sup>1</sup> *Department of Earth & Atmospheric Sciences, Univ. of Houston*

<sup>2</sup> *Science Division, Jet Propulsion Laboratory, Caltech*

<sup>3</sup> *Division of Geological & Planetary Sciences, Caltech*

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# Overview

- **Motivation**
- **Data**
- **Comparisons Between Satellite CO<sub>2</sub> with *In-situ* Measurements**
- **Influence of South Atlantic Walker Circulation on CO<sub>2</sub>**
- **Conclusions**

# Motivation

- **Improve understanding of CO<sub>2</sub> variability and its effect on the global climate change using satellite data**
- **Investigate how natural variability influence the CO<sub>2</sub> distribution**
- **Improve CO<sub>2</sub> simulations from chemistry-transport models in the future**

# Previous Results from AIRS Mid-trop CO<sub>2</sub>

- Significant spatiotemporal variability in the AIRS CO<sub>2</sub>, which is supported by the aircraft observations [*Chahine et al.*, GRL 2008].
- In addition to the annual cycle [*Pagano et al.*, 2014], there is also a semi-annual oscillation in the CO<sub>2</sub> [*Jiang et al.*, GBC 2012; *Ruzmaikin et al.*, JClimate 2012].
- AIRS mid-tropospheric CO<sub>2</sub> concentrations can be modulated by the interannual variability (e.g., ENSO and Northern Annular Mode) [*Jiang et al.*, GRL 2010; *Jiang et al.*, JAS 2013a].
- During a strong (weak) monsoon year, the western Walker Cell is strong (weak), resulting positive (negative) CO<sub>2</sub> anomalies in the AIRS mid-tropospheric CO<sub>2</sub> over the Indo-Pacific region [*Wang et al.*, GRL 2012].
- AIRS mid-tropospheric CO<sub>2</sub> concentrations increase by 2-3 ppm within a few days after the Stratospheric Sudden Warming events [*Jiang et al.*, JAS 2013b].

# Data

## ➤ Satellite CO<sub>2</sub> Retrievals

1. Atmospheric Infrared Sounder (AIRS) V5 Mid-tropospheric CO<sub>2</sub>  
[Chahine *et al.*, 2005; 2008]

Period: Sep 2002 – Present; Sensitivity Peak: 500-300 hPa

2. ACOS/Greenhouse gases Observing SATellite (GOSAT) B3.4  
Column CO<sub>2</sub> [Crisp *et al.*, 2012; Wunch *et al.*, 2011; O' Dell *et al.*,  
2012]

Period: Apr 2009 - Present

3. Tropospheric Emission Spectrometer (TES) Mid-tropospheric CO<sub>2</sub>  
[Kulawik *et al.*, 2012]

Period: Jan 2006 – Present; Sensitivity Peak: 511 hPa

## ➤ *In-situ* CO<sub>2</sub> Data

1. NOAA ESRL Cooperative Air Sampling Network Surface CO<sub>2</sub>  
[GLOBALVIEW-CO<sub>2</sub>, 2010]

2. TCCON Column CO<sub>2</sub> measured by Fourier Transform  
Spectrometer [Washenfelder *et al.*, 2006; Macatangay *et al.*, 2008]

# Model

## ➤ 3-D MOZART-2 Chemistry and Transport Model

Resolution:  $2.8^{\circ} \times 2.8^{\circ}$  (*lat x lon*); 45 vertical layers (0-50 km)

Meteorology: *ECMWF Interim Meteorological Data*

Boundary Condition:  $\text{CO}_2$  Surface Fluxes (Biomass burning [Randerson et al., 2013], Fossil Fuel [Boden et al., 2013], Ocean [Takahashi et al., 1997], Exchange Between Biosphere and Atmosphere [Olsen and Randerson, 2004; van der Werf et al., 2006])

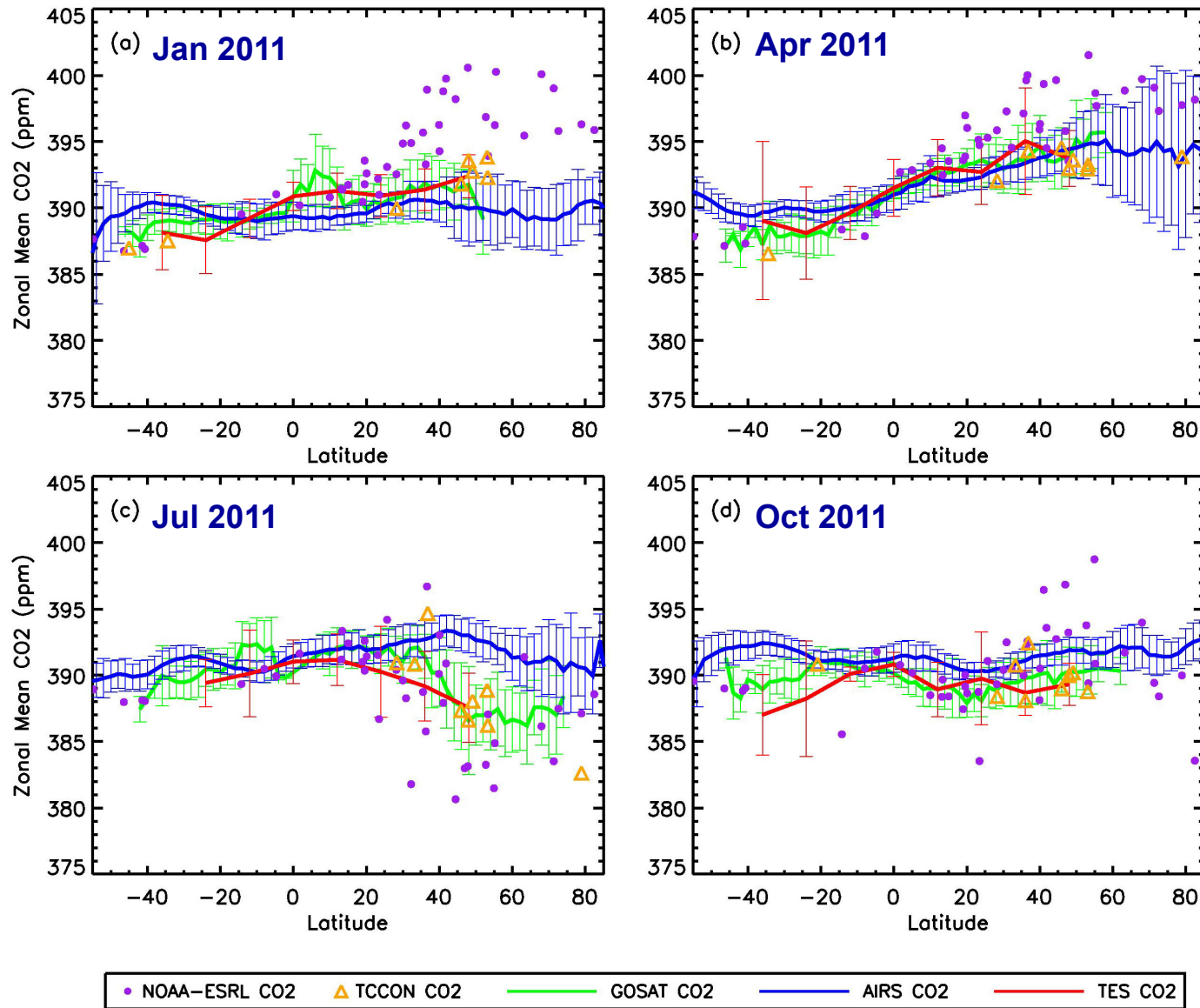
## ➤ 3-D CarbonTracker 2013 Chemistry and Transport Model

Resolution:  $3^{\circ} \times 2^{\circ}$  (*lon x lat*); 34 vertical layers

Meteorology: *ECMWF Operational Forecast Model & ECMWF-Interim*

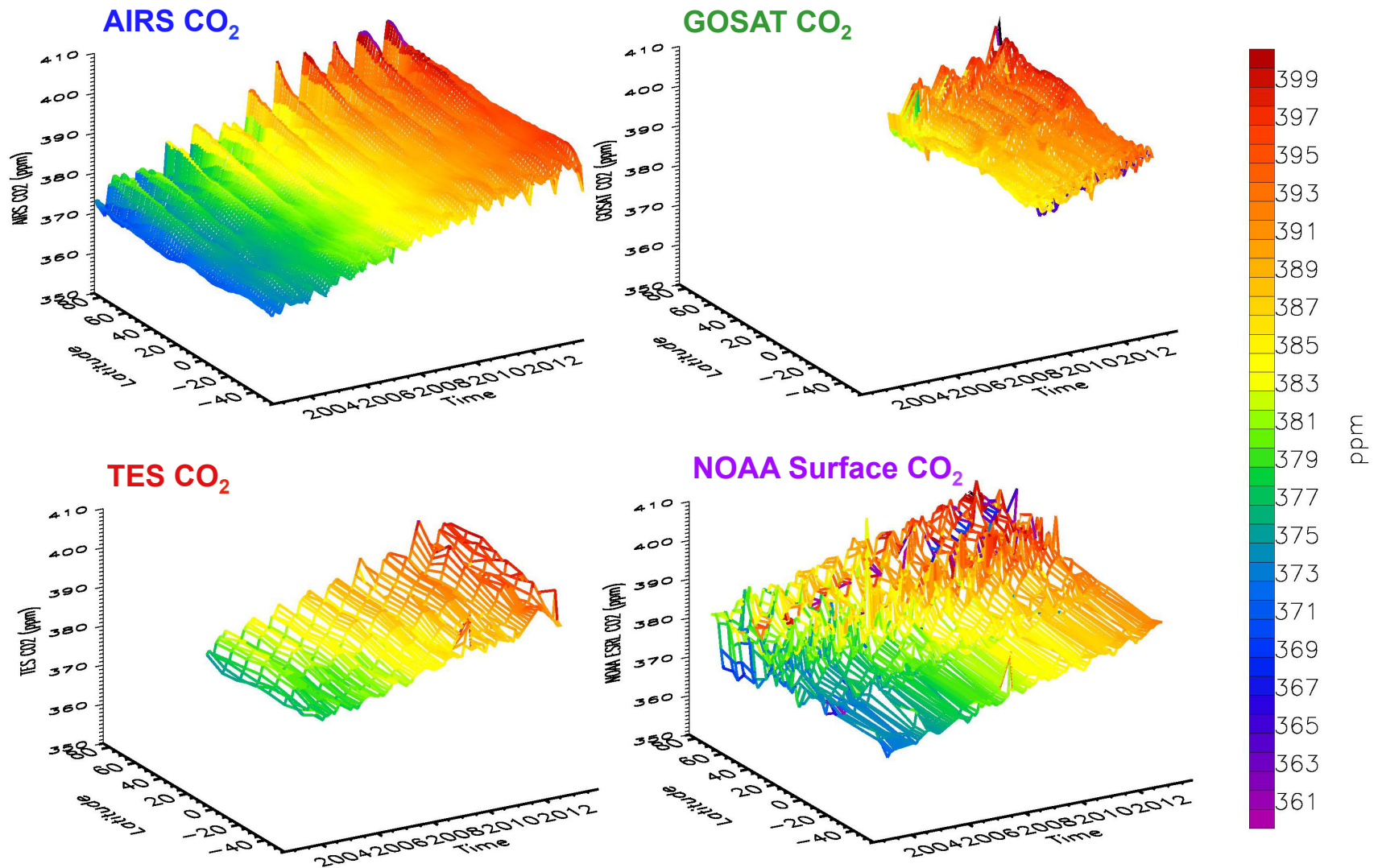
Boundary Condition:  $\text{CO}_2$  Surface Fluxes (Biomass burning [Randerson et al., 2013], Fossil Fuel [Oda and Maksyutov, 2011], Ocean [Jacobson et al., 2007], Exchange Between Biosphere and Atmosphere [Olsen and Randerson, 2004; van der Werf et al., 2006])

# Comparison Between Satellite CO<sub>2</sub> with *In-situ* Observations

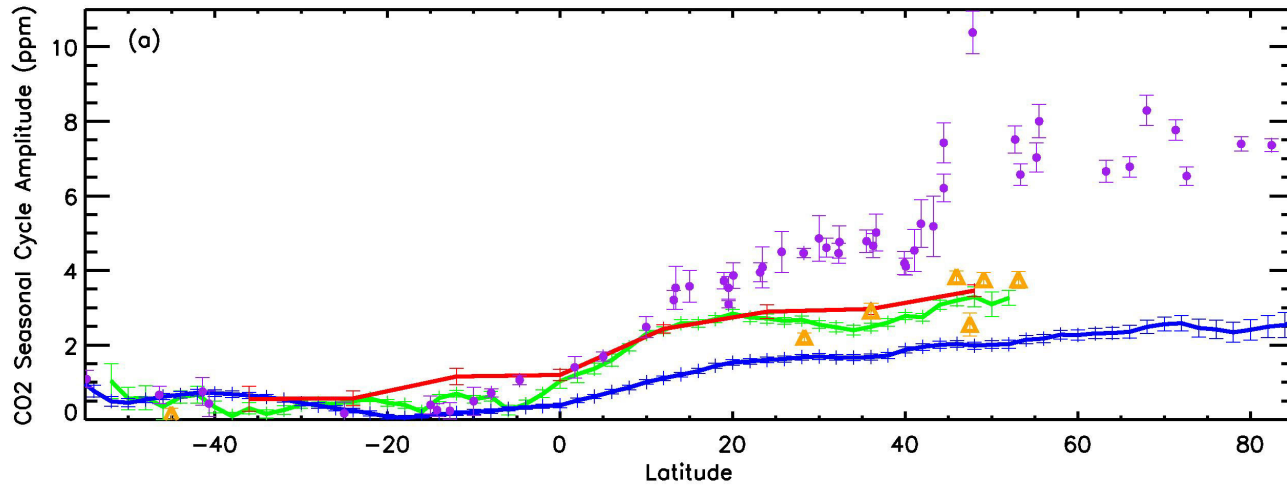


— AIRS mid-tropospheric CO<sub>2</sub>  
— GOSAT column CO<sub>2</sub>; — TES lower mid-tropospheric CO<sub>2</sub>  
• NOAA ESRL Surface CO<sub>2</sub>; △ TCCON column CO<sub>2</sub>

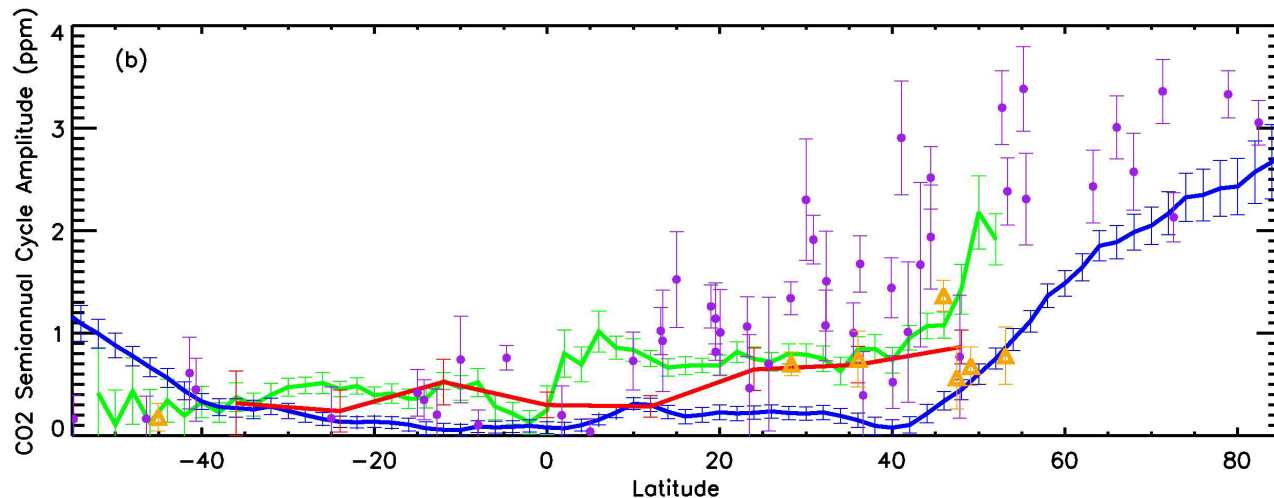
# Comparison Between Satellite CO<sub>2</sub> with *In-situ* Observations



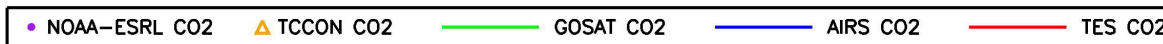
# CO<sub>2</sub> Annual Cycle and Semiannual Cycle Amplitudes



CO<sub>2</sub> Annual Cycle Amplitude

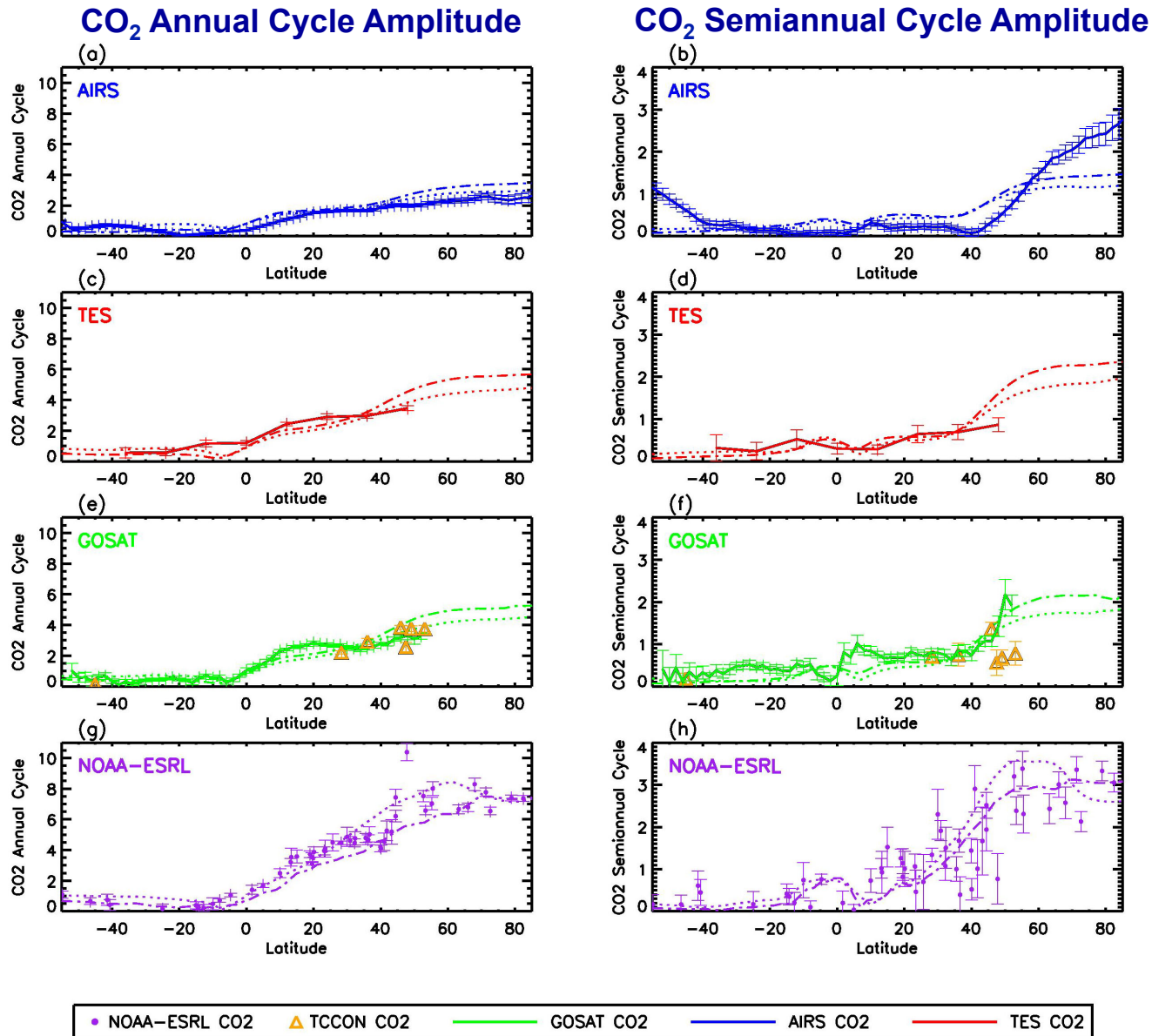


CO<sub>2</sub> Semiannual Cycle Amplitude



— AIRS mid-tropospheric CO<sub>2</sub>  
— GOSAT column CO<sub>2</sub>;    — TES lower mid-tropospheric CO<sub>2</sub>  
• NOAA ESRL Surface CO<sub>2</sub>  
Δ TCCON column CO<sub>2</sub>

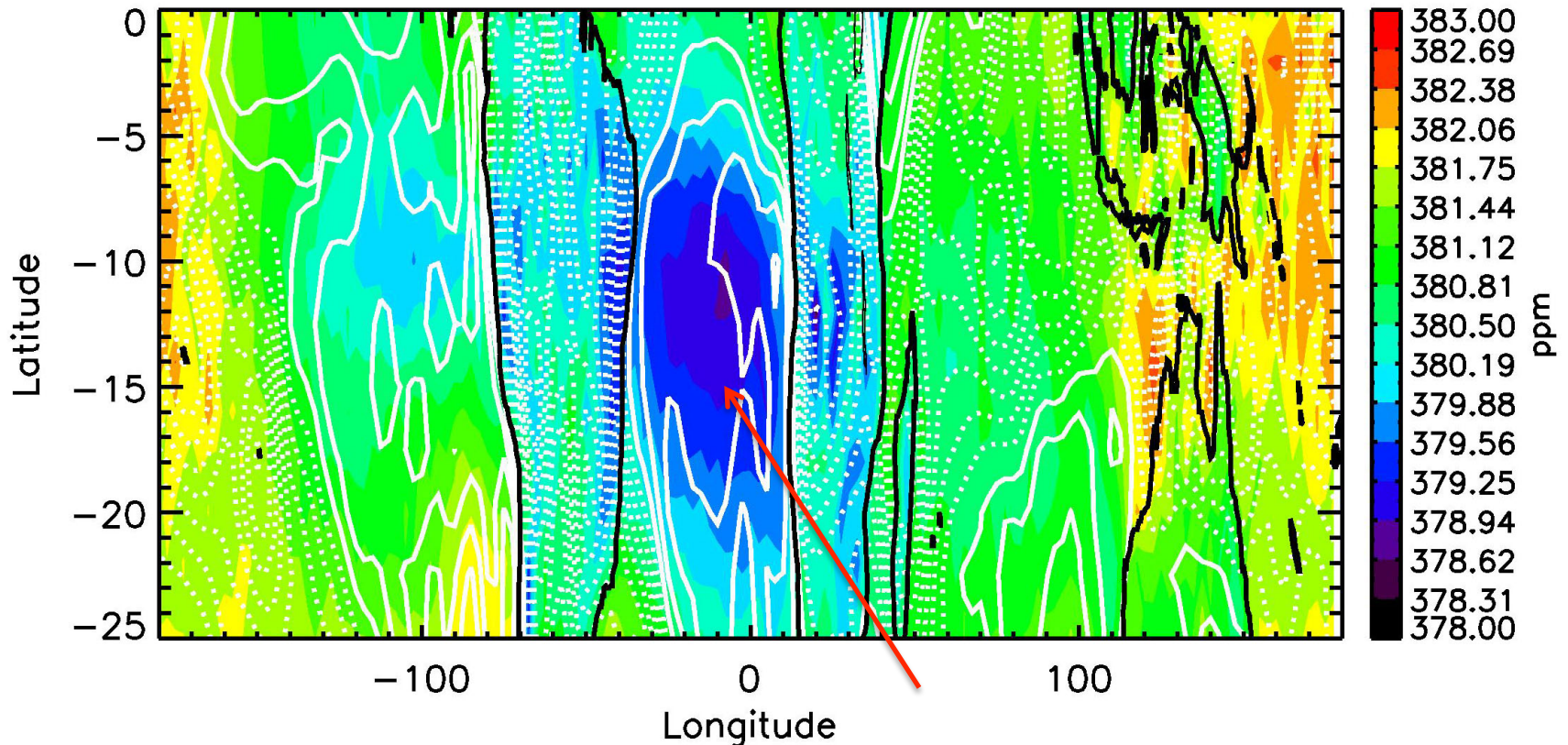
# Model CO<sub>2</sub> Annual Cycle and Semiannual Cycle Amplitudes



**MOZART CO<sub>2</sub> (Dotted line) & CarbonTracker CO<sub>2</sub> (Dash-dot line)**

# AIRS CO<sub>2</sub> in DJFM Averaged from 2003 to 2010

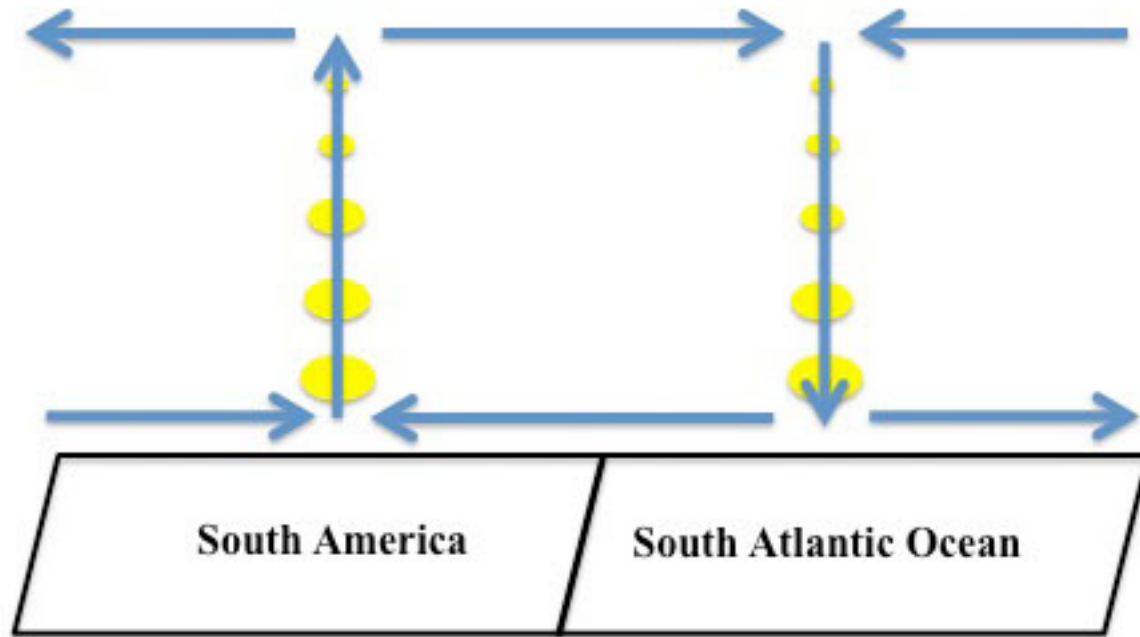
AIRS CO<sub>2</sub> in DJFM



**Solid White Contours: Sinking Air; Dotted White Contours: Rising Air**

**CO<sub>2</sub> difference is ~ 1 ppm between South Atlantic Ocean and South America.**

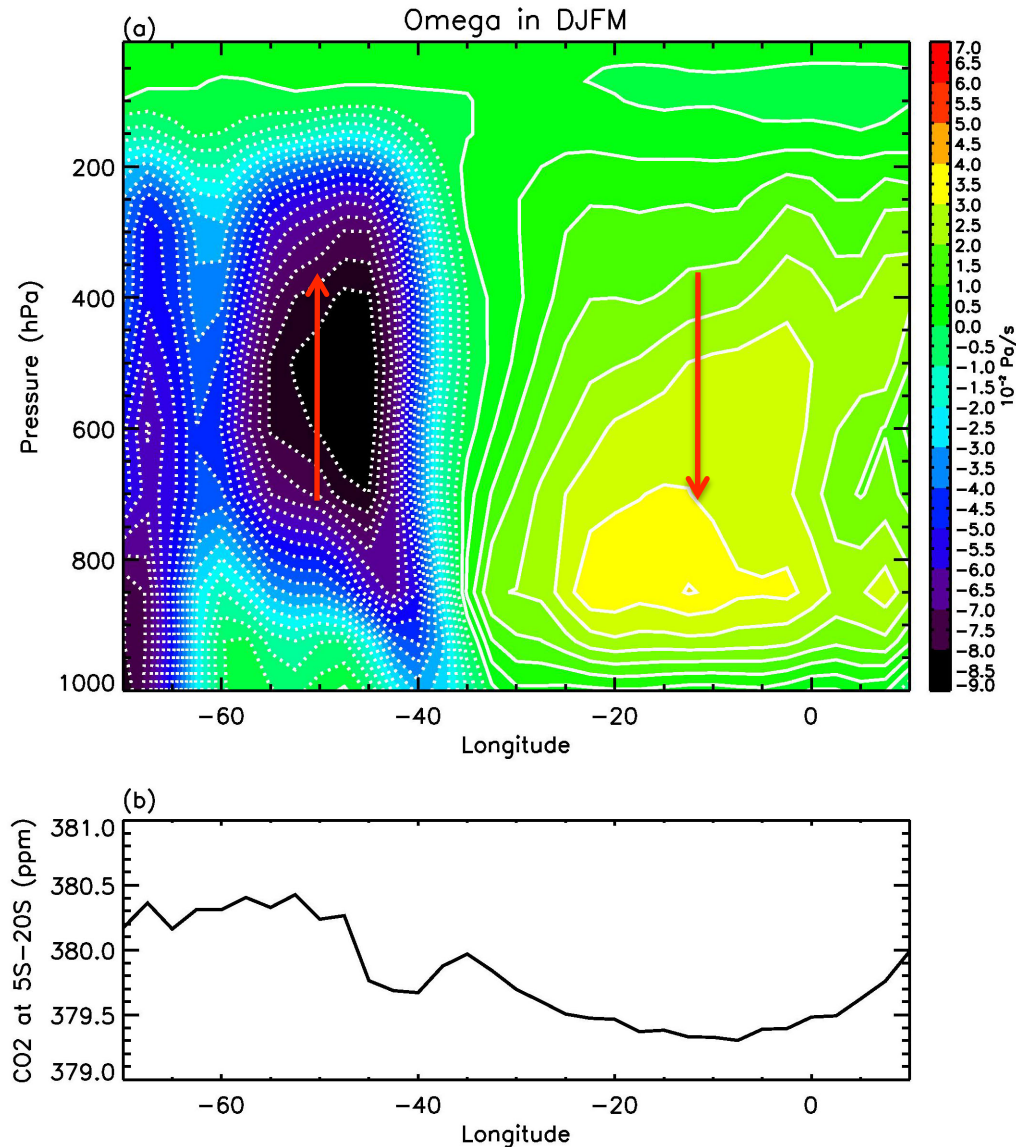
# South Atlantic Walker Circulation



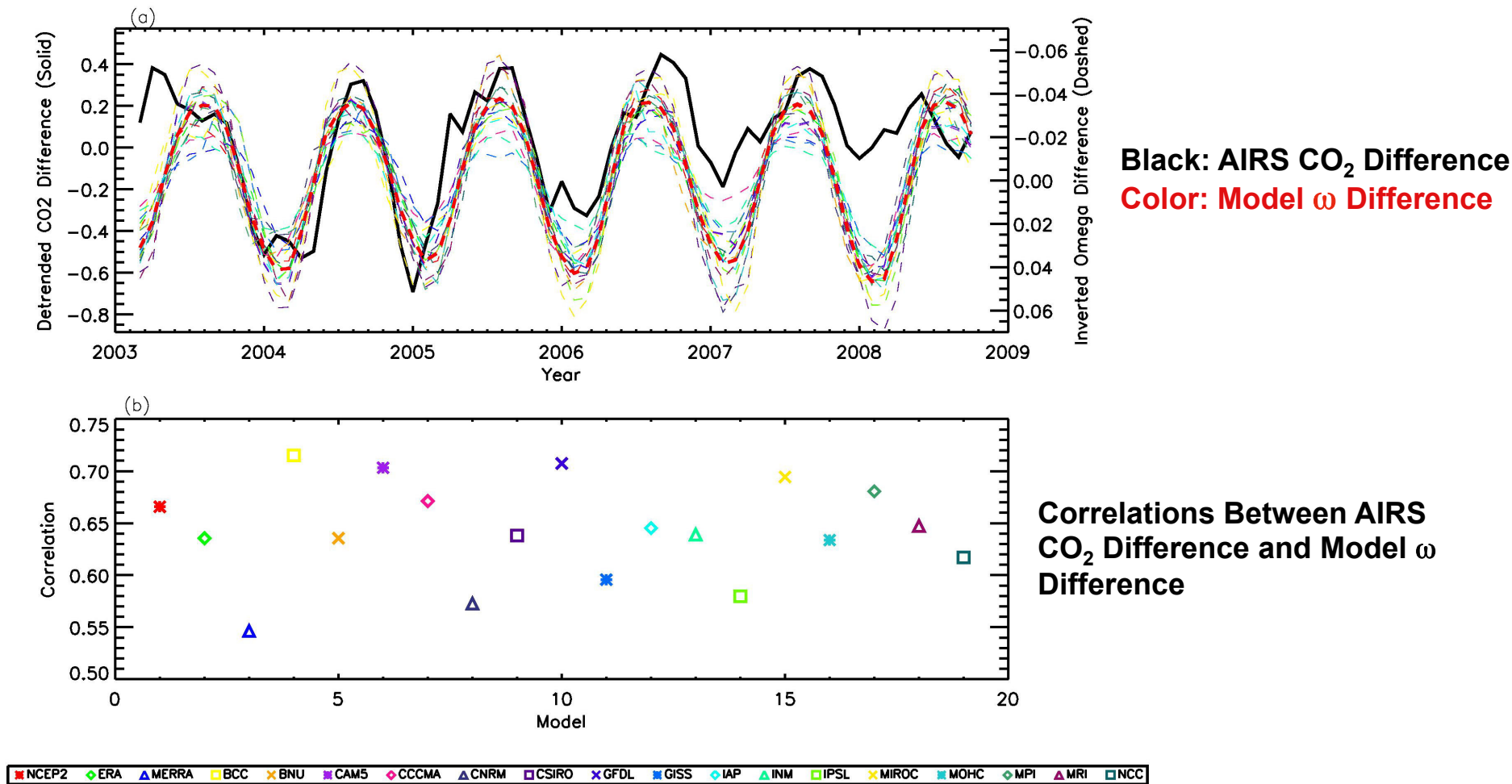
**Sinking air brings high-altitude low concentrations of CO<sub>2</sub> to the mid-troposphere over South Atlantic Ocean.**

**Rising air brings surface high concentrations of CO<sub>2</sub> to the mid-troposphere over South America.**

# Influence of South Atlantic Walker Circulation on CO<sub>2</sub>



# Influence of South Atlantic Walker Circulation on CO<sub>2</sub>



**AIRS mid-tropospheric CO<sub>2</sub> difference correlates well with the inverted and detrended 400 hPa vertical pressure velocity difference between South Atlantic and South America.**

# Conclusions

- Zonal averaged CO<sub>2</sub> for three satellite data sets (AIRS, GOSAT, and TES) are consistent with the surface and TCCON column CO<sub>2</sub> data.
- CO<sub>2</sub> annual cycle and semiannual cycle amplitudes decrease with altitudes. Model convolved CO<sub>2</sub> annual cycle and semiannual cycle amplitudes are similar to those from the satellite CO<sub>2</sub> retrievals.
- Low concentrations of CO<sub>2</sub> are seen over the Southern Atlantic Ocean, which is related to the sinking branch in the Atlantic Walker Circulation.
- AIRS mid-tropospheric CO<sub>2</sub> difference correlates well with the inverted and detrended 400 hPa vertical pressure velocity difference between South Atlantic and South America. AIRS CO<sub>2</sub> can be used as an innovative observational constraint on the simulation of large-scale circulation in climate models.

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Yung

*Thank you!*